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TOWARDS A GENERIC MODEL FOR SITUTATION AND THREAT ASSESSMENT

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TOWARDS A GENERIC MODEL FOR SITUATION AND THREAT ASSESSMENT

by

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ABSTRACT

This document presents a generic model for situation and threat assessment influenced by the human's mental processing. The model evolved from a three-level descriptive model of situation awareness, in which the first level is concerned with perception of the elements in the environment, the second level concerns comprehension of the current situation and the last level deals with projection of future states of the situation. This model leads us to a high-level functional decomposition of a multi-level Situation and Threat Assessment process. The context is naval warfare in which the shipboard commanders and their staff require access to a wide range of information to carry out their duties. The purpose is to support the human to assess the situation and the threat by the automation of some higher level cognitive processing currently performed by the human.

RÉSUMÉ

Ce document présente un modèle générique de l'évaluation de la situation et de la menace d'après le traitement mental de l'usager. Le modèle est développé autour d'un concept descriptif en trois niveaux portant sur la perception de la situation. Le premier niveau de ce concept consiste en la perception des éléments liés à la situation actuelle, le second niveau a trait à la compréhension de la situation actuelle à partir des résultats de la perception de celle-ci, le dernier niveau traite de la prédiction des états futurs de la situation en fonction de la perception et de la compréhension de celle-ci. Le modèle générique est décrit à l'aide d'une décomposition fonctionnelle de haut niveau des différents processus hiérarchisés en trois groupes et liés au traitement de l'évaluation de la situation et de la menace. Le contexte d'utilisation de ce modèle est la guerre maritime au cours de laquelle les commandants de navires et leurs équipages ont recours à une grande variété d'informations pour accomplir leurs tâches. Le but du modèle est d'assister l'usager dans l'accomplissement de ses fonctions par l'automatisation de certaines tâches exigeant un traitement cognitif et actuellement accomplies par l'humain.

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EXECUTIVE SUMMARY

Advances in anti-ship threat technology will place heavy demand (quicker reaction to faster, stealthier threats) for the ability to process and interpret tactical data provided by multiple and often dissimilar sources of information. The volume, rate and complexity of information provided by modern sensors is continuously increasing with evolving technology. The Operations Room will be flooded by a mix of raw data and processed information to a point at which the ability of human operators to cope with this situation may be exceeded. This emphasizes the need for warships to be fitted with an efficient combat system, at the heart of which is a Command and Control System (CCS) which includes an integrated real-time system providing Multi-Source Data Fusion (MSDF) capability, Situation and Threat Assessment (STA) capability and automated Resource Management (RM) capability (including weapons and sensors) to ensure own ship survival and to increase the probability of mission success.

The Data Fusion & Resource Management Group in the Decision Support Technologies Section at Defence Research Establishment Valcartier (DREV) is exploring real-time issues for the development of an integrated MSDF/STA/RM decision support system for the Canadian Patrol Frigate (CPF) in order to improve its performance against current and future threats.

This document presents a generic model for STA influenced by the human's mental processing. The aim of the research is to explore the problem of fusing information provided by Multi-Source Data Fusion (MSDF) with that from external environmental sources of information in order to determine the probable situation explaining the presence, status and intentions of the observed entities as a means of deriving a coherent composite tactical picture of the situation and of anticipating future events over a short-time horizon. The generic model evolved from a three-level descriptive model of situation awareness, in which the first level is concerned with perception of the elements in the environment, the second level concerns comprehension of the current situation and the last level deals with projection of future states of the situation. This model leads us to a high-level functional decomposition of amulti-level Situation and Threat Assessment process.

The results of this research are expected to contribute to DREV's investigations of enhancements to the CPF's CCIS as part of the mid-life upgrade of the CPF under the Frigate Life Extension Program (FELEX).

LIST OF ACRONYMS

AI	Artificial Intelligence
AWW	Above Water Warfare
BA	Behavior Analysis
C^2	Command and Control
CCIS	C^2 Information System
CO	Commanding Officer
CPA	Closest Point of Approach
CPF	Canadian Patrol Frigate
DR	Data Refinement
DF	Data Fusion
DoD	Department of Defense
DREV	Defence Research EstablishmentValcartier
ESM	Electronic Support Measure
FELEX	Frigate Life Extension
HCI	Human Computer Interface
HG	Hypothesis Generator
HV	Hypothesis Validation
ID	Identification
JDL	Joint Directors of Laboratories
JDL/TPC^3	JDL/Technical Panel for Command, Control and Communication
KA	Kill Assessment
KE	Kinematic Estimation
MSDF	Multi-Source Data Fusion
OR	Operational Room
PU	Participating Unit
R&D	Research and Development
RM	Resource Management
SA	Situation Assessment
STA	Situation and Threat Assessment
TA	Threat Assessment
TE	Threat Evaluator
TOF	Time Of Flight
TS	Threat Stabilizer

1.0 INTRODUCTION

The Canadian Patrol Frigate (CPF) is scheduled for a major upgrade around the year 2010 under the Frigate Life Extension (FELEX) Program. In order to have this upgrade performed as scheduled, most R&D work must be completed in the 2005 time frame thereby allowing production work to incorporate the R&D results into the final FELEX deliverables.

Technological advancements of threats to the navy's warships will place heavy demand (quicker reaction to faster, stealthier threats) for the ability to process and interpret tactical data provided by multiple and often dissimilar sources of information. The volume, rate and complexity of the information provided by modern sensors is continuously increasing with evolving technology. The Operations Room of the ship will be flooded by a mix of raw data and processed information to a point at which the ability of human operators to cope with this situation may be exceeded. This emphasizes the need for the Canadian Patrol Frigate (CPF) to be fitted with an efficient combat system at the heart of which is a Command and Control System (CCS) which envisaged to include an integrated real-time system providing Multi-Source Data Fusion (MSDF) capability, Situation and Threat Assessment (STA) capability and automated Resource Management (RM) capability (including weapons and sensors) to ensure own ship survival and to increase the probability of mission success. The R&D work for the development of the future shipboard CCS is therefore of prime importance.

A major ongoing activity undertaken by the Data Fusion Group in the Decision Support Technologies Section at Defence Research Establishment Valcartier (DREV) is to explore real-time issues for an integrated MSDF/STA/RM system for the CPF in order to improve its performance against current and future threats.

This document presents a generic model for STA influenced by the human's mental processing. The aim of the research is to explore the problem of fusing information provided by Multi-Source Data Fusion (MSDF) with that from external environmental sources of information in order to determine the probable situation explaining the presence, status and intentions of the observed entities as a means of deriving a coherent composite tactical picture of the situation and of anticipating future events over a short time horizon. The generic model from a three-level descriptive model of situation awareness, in which the first level is concerned with perception of the elements in the environment, the second level concerns comprehension of the current situation and the last level deals with projection of future states of the situation. This model leads us to a high-level functional decomposition of a multi-level Situation and Threat Assessment process. The purpose is to support the human to assess the situation and the threat by the automation of some higher level cognitive processing currently performed by the human.

This document is organized as follows. Chapter 2 introduces the fundamental concepts related to Situation and Threat Assessment (STA). In Chapter 3, a generic model for STA is presented and the major components of this model are described. Finally, Chapter 4 contains concluding remarks.

This work was carried out at DREV between January and September 1996 under Work Unit 1ae12 : Investigations of MDSF/STA/RM Concepts.

2.0 FUNDAMENTALS OF SITUATION AND THREAT ASSESSMENT

This section presents fundamental concepts related to Situation Assessment (SA) and Threat Assessment (TA). A traditional definition of the multi-level data fusion process, taken from the literature, is given, focusing on the Situation and Threat Assessment (STA) sub-processes. Some other important definitions pertinent to the domain are also given. The objective is to provide the reader with the essential background knowledge needed to understand and evaluate the proposed generic Situation and Threat Assessment model presented in the next section.

2.1 Data Fusion

2.1.1 Definition

Throughout the 1980s, the three U.S. military services pursued the development of data fusion in tactical and strategic surveillance systems and supported extensive research in the areas of target tracking, target identification, algorithm development for correlation (association) and classification, and the application of intelligent systems to situation assessment (Ref. 1). The large amount of fusion-related work in this period raised some concerns over possible duplication of effort. As a result, the Joint Directors of Laboratories (JDL) for the U.S. Department of Defense (DoD) convened a Data Fusion Subpanel to

(1)survey the activities across all services

(2)establish a forum for the exchange of research and technology

(3)develop models, terminology and a taxonomy of areas for research and development in the area of operational systems.

As a result of many years of effort to establish standardization and stability in the lexicon of data fusion, the definition of many terms is slowly achieving consensus across the diversified application community (Ref. 2). Problem-specific nuances and shading in these definitions remain, but agreement on a meaningful subset of terms does seem to exist, providing an important basis for communication across specialized research groups.

Data Fusion (DF) is fundamentally a process designed to manage (i.e., organize, combine and interpret) data and information, obtained from a variety of sources, that may be required at any time by operators and commanders for decision making. The sources of information may be quite diverse, including sensor observations, topographic and environmental data, data describing capability and availability of targets, and information regarding doctrine and policy. The data and information provided by these various sources may contain a number of targets, conflicting reports, cluttered backgrounds, degrees of error, deception, incompleteness, and ambiguities about events or behaviors.

In this context, DF is an adaptive information process that continuously transforms the available data and information into richer information, through continuous refinement of hypotheses or inferences about real-world events, to achieve refined (and potentially optimal) kinematics and identity estimates of individual objects, and complete and timely assessments of current and potential future situations and threats (i.e., contextual reasoning), and their significance in the context of operational settings.

The DF process is also characterized by continuous refinements of its estimates and assessments, and by evaluation of the need for additional data and information sources, or modification of the process itself, to achieve improved results.

2.2 Data Fusion Hierarchy

The process of data fusion may be viewed as a multi-level hierarchical inference process whose ultimate goal is to assess a mission situation and identify, localize and analyze threats. However, not every data fusion application is responsible for all of these outputs. Some applications are only concerned with the position and identification of objects. Other applications are primarily oriented towards the situation and how it is evolving. Still, others focus on the threat and its possible impact upon achieving mission objectives. In addition, the data fusion function can be responsible for identifying what information is most needed to enhance its products and what sources are most likely to deliver this information.

Given these considerations, a complete data fusion system can typically be decomposed into four levels:

- Level 1 - Multi-Source Data Fusion (MSDF);
- Level 2 - Situation Assessment (SA);
- Level 3 - Threat Assessment (TA); and,
- Level 4 - Process Refinement Through Resource Management (RM).

Each succeeding level of data fusion processing deals with a higher level of abstraction. Level 1 data fusion uses mostly numerical, statistical analysis methods, while Levels 2, 3 and 4 of data fusion use mostly symbolic or Artificial Intelligence (AI) methods. Note that resource management in the context of Level 4 fusion is mainly concerned with the refinement of information gathering process (i.e., sensor management). However, the overall domain of resource management also encompasses the management of weapon systems and other resources. Figure 1 illustrates the overlap between the data fusion and resource management domains.

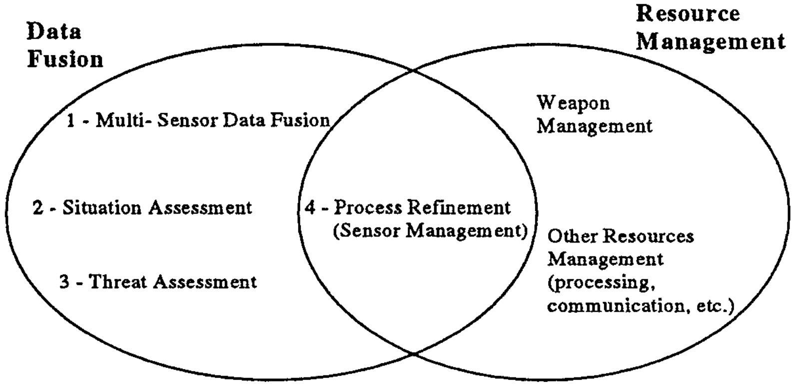

FIGURE 1 - Overlap between the data fusion and resource management domains

2.2.1 Multi-Source Data Fusion

Multi-source data fusion (MSDF) is concerned solely with individual objects, first in associating the sensor outputs with specific known objects or using them to initiate new objects. Level 1 processing uses sensor data to correctly and quickly derive the best estimates of current and future positions for each hypothesized object. In addition, inferences concerning the identity of the objects and key attributes of the objects are developed.

Key MSDF functions include: data alignment, data association/correlation, kinematic data fusion, target state estimation, target kinematics behavior assessment, target identity information fusion and track/cluster management.

2.2.2 Situation Assessment

Situation Assessment (SA) is a topic of recent research and is consequently an immature field in comparison with MSDF. This explains the existence of so many formal definitions of the concept of situation assessment in the literature and highlights the imprecise and disparate interpretations in different papers. The data fusion sub-panel[2] of the JDL/TPC3 defines SA, also known as situation refinement, as the Level 2 processing which develops a description or interpretation of current relationships among objects and events in the context of the operational environment. The result of this processing is a determination or refinement of the battle/operational situations. Key functions include :

1. Object Aggregation - Establishment of relationships among objects including temporal relationships, geometrical proximity, communications links and functional dependence.
2. Event/Activity Aggregation - Establishment of relationships among diverse entities in time to identify meaningful events or activities.

3. Contextual Interpretation/Fusion - Analysis of data with respect to the context of the evolving situation including weather, terrain, sea-state, or underwater conditions, enemy doctrine and socio-political considerations.
4. Multi-perspective Assessment - Analysis of data with respect to three perspectives: (1) the blue (friendly) force; (2) the red (enemy) force; and (3) the white (neutral) - how the environment affects red and blue perspectives.

Other authors (Refs. 3-5) have come up with more detailed definitions of SA derived from the JDL model and linked with a conceptual model and functional decomposition in order to provide a better understanding of the concept. The commonality of each of these definitions coupled with research work at DREV will be used to state the definition of SA that underlies the development of the generic model for Situation and Threat Assessment presented in the next section.

2.2.3 Threat Assessment

Threat assessment (TA) is focused on the details necessary for decision makers to reach conclusions about how to position and commit the friendly forces. It can be viewed as a longer term diagnosis function to determine problems in the current situation and identify opportunities for taking corrective actions.

By coupling the products of situation assessment with the information provided by a variety of technical and doctrinal databases, TA develops and interprets a threat-oriented perspective of the data to estimate enemy capabilities and lethality, identify threat opportunities, in terms of the ability of own force to engage the enemy effectively, estimate enemy intent (i.e., provide indications and warnings of enemy intentions), and determine the levels of risk and danger.

Hence, TA uses the situation picture from Level 2 and what is known about the enemy doctrine and objectives to predict the strengths and vulnerabilities for the threat and friendly forces. In addition, the friendly mission and specific options available to the decision makers are tested within these strengths and vulnerabilities to guide decision making.

Key TA functions include: enemy forces capability estimation, predict enemy intent, identify threat opportunities, multi-perspective assessment and offensive/defensive analysis.

2.2.4 Resource Management

Information resource management, Level 4 processing, closes the loop by first examining and prioritizing what is unknown in the context of the situation and threat and then developing options for collecting this information by cueing the appropriate sensors and collection sources.

Within the scope of more general resource management issues (weapons, sensors, etc.), Situation and Threat assessment, together with command team interaction, as required or as response time permits, provides input to the planning and decision support functions for allocating and scheduling the use of critical defence resources and coordinating defence actions in support of the mission. Determination of the various options for resource usage and the selection of the best course of action in a given situation is known as Resource Allocation. Resource Management refers to the continuous process of planning, coordinating and directing the use of the ship or force resources to counter the threat. It is concerned with issues of both command and control.

3.0 GENERIC MODEL FOR SITUATION AND THREAT ASSESSMENT

In this chapter, we present and discuss ideas related to the field of Situation and Threat Assessment in the context of tactical, shipboard Naval Command and Control. First, the definition of STA underlying the development of the generic model for Situation and Threat Assessment is introduced and discussed along with the new concepts and ideas associated with it. Then, the generic conceptual model for STA is presented and its functional decomposition is briefly described. Finally, we situate this generic model with ongoing research work studying the integration of MSDF, STA and RM.

3.1 New Concepts

Previous work on Data Fusion has tended to restrict the human to an observer's role and thereby to exclude him from the process. In fact, the JDL high-level functional model of the Data Fusion process suggests a hierarchy of sub-processes that could lead to the design and implementation of a totally automated system.

Our approach departs from this perspective. Rather, it is concerned with the reinsertion of the human in the loop by understanding the human's mental processes. On a ship, the Data Fusion process takes place in a room, called the operations room (OR), where all the functions are accomplished by either the human, the machine (computers, sensors...), or a combination of both. The DF process constitutes a set of tasks that can be characterized as either reactive (immediate response) or deliberative. Currently, in the OR, most of the reactive processing is done by the machine and the deliberative processing is done by the human. This is no surprise since the machine with its computational power is without doubt the most efficient means to execute reactive tasks. Similarly, the human with his reasoning capabilities is best suited for performing deliberative tasks.

The volume, rate and complexity of the information provided by modern sensors is continuously increasing with evolving sensor and threat technology. The operations room will be flooded by a mix of raw data and processed information to a point at which may exceed the ability of the human operators to cope with the situation. A key element to support the human could be the automation of some higher level cognitive processing tasks currently performed by the human under STA taking into consideration the cognitive aspects of human information processing.

In the context of Above-Water Warfare (AWW), SA and TA are the active processes by which the decision maker in the ship's operations room achieves awareness of the tactical situation in light of their goals. Endsley[7] defines situation awareness as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. It can be interpreted as the operator's mental model of all pertinent aspects of the environment (process, state, relationships). Figure 2 represents the three levels of situation awareness (the state) derived as products of the processes of Situation and Threat Assessment.

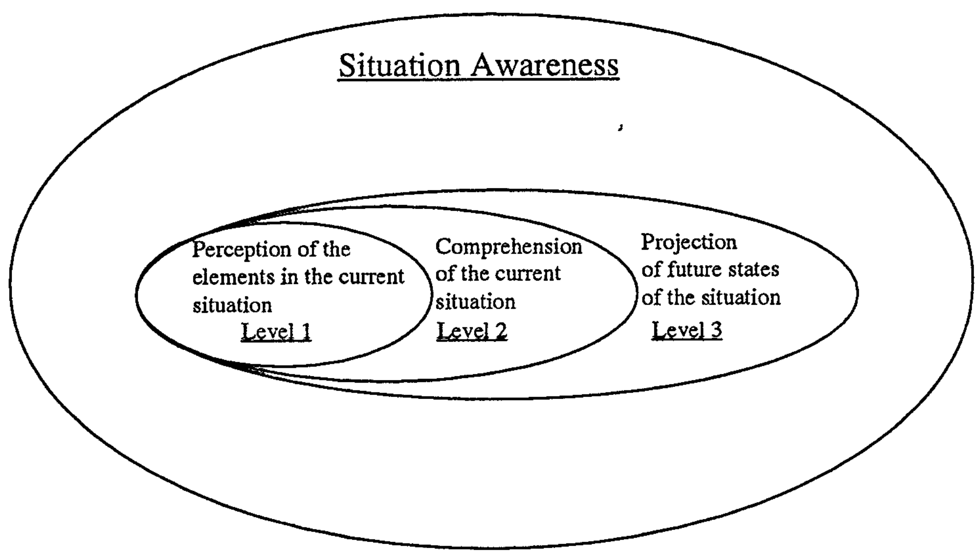

FIGURE 2 - Three levels of situational awareness according to Endsley's model

Obviously, Situation and Threat Assessment is composed of two linked processes : Situation Assessment and Threat Assessment. The SA process monitors the external environment to produce a situation description. Then, SA develops a higher level interpretation of the evolving dynamic situation description, based on a priori knowledge and transient information, and in terms of the current relationships among the perceived domain elements in the context of the operational environment and current mission goals. Therefore, the ultimate goal of SA is to determine the probable situation explaining the presence and the status of the observed entities in the environment in order to enhance awareness of the tactical situation. The result of SA is a coherent composite tactical picture of the current situation along with a short-term prediction of the situation. The tactical picture is described in terms of groups or organizations of objects to be used for the enhancement of the Commanding Officer's (CO) situation awareness and for the threat evaluation which is carried out in TA.

The second process of STA, TA, evaluates and ranks threats on the basis of information obtained from dynamic tactical picture as well as from a priori knowledge and transient information. The result of TA is a ranked threat list used, by Resource Management where decisions are made about how to use war fighting assets in support of the mission.

Efficient automation of some STA deliberative tasks should be carried out taking into consideration the cognitive aspects of human information processing. We propose a high-level functional decomposition of the processes of STA. We refer to this decomposition as the generic model for Situation and Threat Assessment. It is motivated by Endsley's definition of situation awareness while, at the same time, giving consideration to the human-computer analogy that forms the basis of human information processing theory.[8]

Although a difficult problem, the real challenge in command decision support technology remains in the implementation of a Situation and Threat Assessment system that will complement or support decision-makers. Such a system must be designed so that the operator will trust and use it. The ultimate goal should be to implement a system that executes the Situation and Threat Assessment process faster and more efficiently by a human-machine combination working in synergy.

3.2 Generic Model for Situation and Threat Assessment

A first cut of the generic model for Situation and Threat Assessment is illustrated in Fig. 3, focusing on a high-level functional decomposition of STA. The proposed model consists of a Perception Refinement module, a Threat Refinement module, a Situation Interpretation module, a Situation Projection module, a Monitoring module and a Diagnosis module. The generic model has access to a priori knowledge and transient information and its behavior is modulated by a Meta-Controller taking account of processing priorities, processing time and information quality .

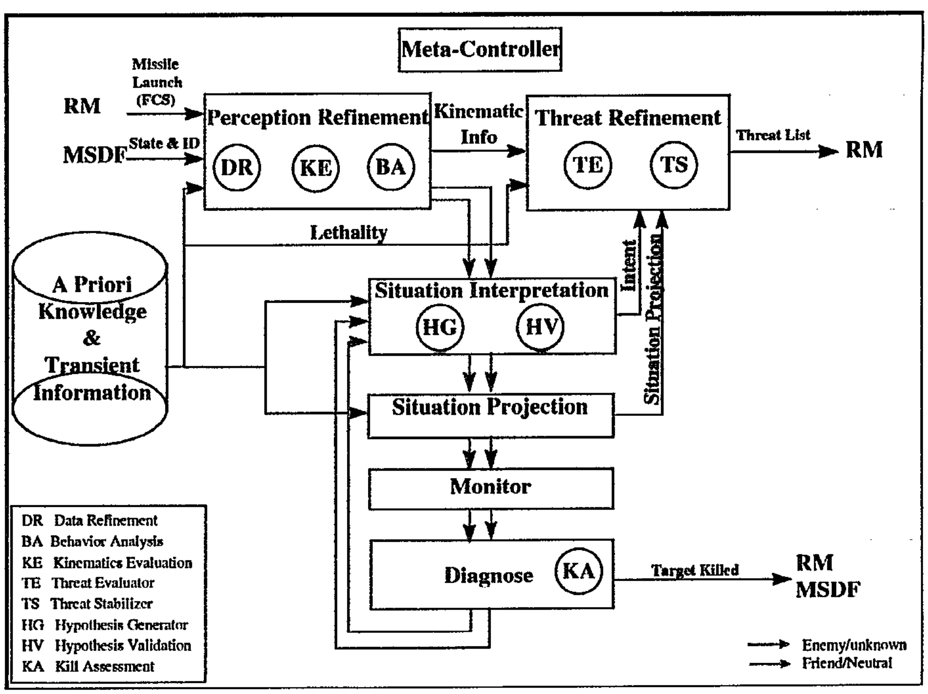

FIGURE 3 - Generic model for STA

The proposed model evolved from a three-level descriptive model of situation awareness, where the first level is related to perception of the elements in the current situation, the second level is about comprehension of the current situation and the last level deals with projection of future situation states. This model yields a high-level functional decomposition of amulti-level STA process.

3.2.1 The inputs and outputs of the model

3.2.1.1 Inputs

The inputs of the generic model for STA are dynamic since they are provided by RM, MSDF and external sources and they evolve in time. Inputs of the model can be categorized as organic and non-organic information.

3.2.1.1.1 Organic information

Inputs of the model controlled, collected and managed by assets under the Commanding Officer's (CO) direct control can be defined or characterized as organic information. Organic information must be sufficiently timely and accurate to be used in real-time, responsive systems. Consequently, it can be used to produce a local tactical picture describing the situation in order to support all of the commander's activities at sea.

For instance, track information, as explained earlier, is provided by MSDF and constitutes the main part of the input to STA. It is characterized as organic information and consists of kinematic information (position, velocity...) and the identity of a perceived entity. This information is sent to the Perception Refinement module. The Resource Management process also provides the Perception Refinement module with track information. The track information provided is about own ship countermeasure actions (Fire-Control Solution), so that it can recognize the track and associate contacts pertaining to the own ship missile, which are perceived within the MSDF process. Here are some other examples of organic information :

• Datalink (e.g. Link-11)

• ESM

• Weather

• etc.

3.2.1.1.2 Non-organic information

Inputs of the model collected by agents not under the CO's direct control, are referred to as non-organic information. This type of information is primarily used by ashore systems to provide some sort of global situational awareness. Some of this information can be of considerable interest to refine the local tactical picture. Non-organic information is less timely, reduced in accuracy, differently structured and has differing identification confidence levels. For these reasons, it cannot be easily integrated into real-time and responsive systems.

Transient information such as intelligence reports or participating unit's information is non-organic and provides additional means for enhancing the commander's situation awareness. This information is used by the Perception Refinement module, the Threat Refinement module, the Situation Interpretation module and the Situation Projection module. The information is used to refine track information, to generate cues for the Situation Interpretation module, to validate hypotheses and to influence threat evaluation.

3.2.1.1.3 Other inputs

Another source of input to the model, which is not shown in Fig. 3, is the human contribution to the STA process through the Human Computer Interface (HCI). A complete and efficient automation of all deliberative tasks carried out in STA is not in the foreseeable future. So it is fair to say that these tasks are to be accomplished by a combination human/machine (to be determined) for efficient results. Consequently, it is obvious that human will participate actively by providing inputs, based on experience, training and awareness of the situation within the STA process. The precise nature of this human-computer interaction remains to be determined.

3.2.1.2 Outputs

The results or outputs of the STA process consist of a stabilized and ranked threat list, result of Kill Assessment (KA) process, and feedback to the human concerning the tactical picture.

The threat list, which is obtained from the Threat Refinement process, is passed to the Resource Management process, where decisions are taken about how to use war fighting assets in response to threats.

The second output of the model, resulting from the KA process, is passed to both MSDF and RM processes respectively as a means of updating the tactical picture and providing input to planning and engagement actions.

Another output of the model, which is not shown in Fig. 3, is a high level interpretation of the tactical situation which is sent to the CO, through the HCI, in order to enhance the situational awareness of the battle environment.

One has to wonder whether the Perception Refinement module, the Situation Interpretation module and the Diagnosis module, described later in this section, should be producing outputs that could be useful to MSDF processing, e.g. hypotheses of possible clusters that could provide evidence of missing tracks.

3.2.2 A Priori Knowledge

A Priori Knowledge contains static information as a means to support the various processes providing the commander with a gain in a level of situation awareness. This knowledge is a component within the model as opposed to inputs derived from external sources. A Priori Knowledge is used by the Perception Refinement module, the Threat Refinement module, the Situation Interpretation module and the Situation Projection module. The information is used to refine track information, to generate cues for the Situation Interpretation module, to validate hypotheses and to influence threat evaluation. A priori knowledge can be mapped in a human information processing model as long term memory. Here are some examples of a priori knowledge sources:

- social and political
- geographical
- platform characteristics
- mission guidelines
- weapon characteristics
- corridor and flight paths
- EM characteristics
- lethality
- emitter characteristics
- doctrines
- etc.

3.2.3 The Perception Refinement module

The Perception Refinement module corresponds to the first level of Endsley's model. All of the processing related to low-level information such as entities (track data) and groups of entities (clusters) is addressed in this module. The first goal of this module is to refine data by examining track attributes (position, identity) from MSDF for incompleteness and contradictions, and then attempting to establish relationships among these entities in order to form clusters. The second goal of the Perception Refinement module is to estimate kinematic parameters for weapon engageability calculations, which are performed in RM. The last goal of this module is to perform behavior analysis of entities and/or clusters in order to help refine the data set and also to provide the necessary requirements (cues) for the interpretation and understanding of the tactical situation done within the Situation Interpretation module (explained in a later section of this chapter).

If the allegiance of the track, as first estimated by MSDF and refined in this module, is either a foe or an unknown, the refined data is passed directly to the Threat Refinement module defined in a later section. If time permits deliberation, the process will, independently of the track's allegiance, transmit to the Situation Interpretation module the cues generated by the Behavior Analysis sub-process for higher level situation awareness processing.

The Perception Refinement module is composed of three sub-processes : the Data Refinement (DR) sub-process, the Kinematic Estimation (KE) sub-process and the Behavior Analysis (BA) sub-process.

The idea of DR is to refine the track data (position, identity) already generated by MSDF by examining the data set for incompleteness and contradictions and to establish relationships among the entities (in terms of proximity, functionality and dependency) with the help of external data sources if necessary. In the process, no inferences about the situation are generated. The only results obtained from this sub-process are perceptual refinements.

The Kinematic Estimation sub-process is used to compute of kinematic information (mean line of advance, closest point of approach (CPA), time of flight (TOF)...) of a track in preparation for Threat Refinement processing, and for weapon engageability calculations done in RM. A history function, which records the positional tracking and identification information in time, is needed to accomplish these kinematic calculations. The recording of the track information will also allow us, through a history function, to address enemy information countermeasures (i.e., information warfare).

Behavior Analysis (BA) is the last sub-process under Perception Refinement and is used to analyze the behavior of entities and/or clusters in order to help refine the data set.

Also, BA becomes a preliminary step for the second level of the situation awareness model by providing processing cues or evidence about track behavior or cluster status to the Situation Interpretation module for the interpretation and understanding of the current tactical situation. The cues are obtained based on DR analysis of refined information (track and cluster's kinematic data and identification), from a priori knowledge and from transient information (i.e. electronic emissions from ESM, datalink, information from participating units...). BA includes functions, such as corridor correlation, maneuver/pattern identification which generate the required cues to make inferences about the tactical picture. The output of BA, if time permits deliberation, is interpreted within the Situation Interpretation module which is explained below.

3.2.4 The Situation Interpretation module

The Situation Interpretation module is the final processing step to achieve the second level of situation awareness. The Situation Interpretation module is defined as a deliberative module that generates and validates hypotheses about the current tactical situation based on the outputs of the Perception Refinement module, a priori knowledge and transient information. Therefore, the Situation Interpretation module explains the presence of the perceived entities and determines the intent of enemy or unknown tracks. In addition, if the track's allegiance is currently perceived as a foe or unknown, the module influences the threat assessment done within the Threat Refinement module as explained later in this chapter. Finally, the results of this module are passed to the Situation Projection module, independently of the track's allegiance.

The Situation Interpretation module is composed of two sub-processes: the Hypothesis Generator (HG) and the Hypothesis Validation (HV). The first is used for each new entity or event to generate one or several hypotheses about the probable situation causing the perceived domain element (track, cluster). These new hypotheses are obtained based on the outputs of the Perception Refinement module, a priori knowledge and transient information and are validated by HV for inconsistencies, conflicts of information and potential inaccuracies due to incomplete data.

The goal of the Hypothesis Generator process is to provide possible explanation of the role and purpose of each perceived entity within the domain. In the case of friend/neutral allegiance, the intent is relatively straightforward to determine due to the cooperative nature of the entity. Hypotheses about the enemy/unknown's intent are likely to be more variable due to the non-cooperative nature of the entity. Independently of the allegiance, all hypotheses need an iterative validation process to acquire and modify the confidence level associated with each hypothesis. To do this, the HV process takes cues from the Diagnose module (explained later in a subsection) along with an updated situation description and modifies the hypotheses and their confidence levels to reflect current understanding of the state of the world. Finally, the resulting hypotheses are fed into the Situation Projection module for further processing and also into the Threat Refinement module for threat evaluation calculations.

3.2.5 The Situation Projection module

The Situation Projection module concerns the last of the three levels of the Situation Awareness model: projection of future states. The Situation Projection module is a deliberative process that generates hypotheses about the future states of the tactical situation based on outputs of the Situation Interpretation module and the a priori knowledge. The results of the Situation Projection module are passed to the Threat Refinement module as input to threat number calculations and, are then submitted to the Monitor module to continue the situation assessment processing.

3.2.6 The Monitor module

The Monitoring module is in fact a process that stores expectancies such as hypotheses about future events and anticipation of Kill Assessments (KAs), and monitors the situation to collect cues until a diagnosis can be given, which is done by the Diagnose module. The goal of this module is to monitor the situation for potential violations of expectancies generated by the Situation Projection module, which suggest that the current situation interpretation is in error.

3.2.7 The Diagnose module

The Diagnose module measures the discrepancies between expectancies and the currently perceived state of the world and diagnoses the nature of these discrepancies. These diagnoses are fed back to the Situation Interpretation module for further interpretation and validation.

The Diagnose module also assesses expectancies related to countermeasures taken by RM, called Kill Assessment Briefly, KA consists in assessing the kill (soft or hard) of an entity by monitoring the results of own ship countermeasure actions. The result of this particular expectancy is sent back to MSDF for an update of the tactical picture and to RM for an update of engagement plans.

3.2.8 The Threat Refinement module

This module assesses potential threats and produces a stabilized and ranked threat list based on the opportunity, lethality and intent of the threat, and a short-term prediction of the situation. The Threat Refinement module is composed of two processes: the Threat Evaluator (TE) and the Threat Stabilizer (TS).

The Threat Evaluator sub-process evaluates threat of unknown or enemy tracks based on opportunity and lethality information. The threat assessment is also refined using intent and situation prediction outputs from the situation interpretation and situation projection processes, respectively.

The opportunity can be determined with respect to own ship or another ship. For instance, the opportunity of air threats is determined, on the CPF, from the closest point of approach (CPA) and time of flight (TOF) calculations along with the target's mean line of advance and velocity.

The lethality estimation is based on a priori knowledge and transient information (intelligence reports for example) of the target characteristics, the weapons on board the target, the characteristics of these weapons and their status.

The intent of an air threat is estimated in the situation interpretation module and can raise or lower the threat level depending on current track behavior. For instance, if an anti-ship missile is locked onto a ship and the ship has proof of this fact from its sensors, this situation is obviously more dangerous than when the missile seeker head is passive. As another example, a multi-mission bombing aircraft that is only doing reconnaissance would be considered less dangerous than the same aircraft if it were carrying out a bombing mission. In the latter case, therefore, the intent would influence the threat assessment

Finally, a situation prediction used together with the appropriate subfunctions of the diagnosis process could give better estimates of opportunity and intent and thus refine the threat assessment.

The threat stabilizer (TS) is a process that prevents the outputs of TE from oscillating. In the case of maneuvering targets approaching a warship, the closest point of approach (CPA) can vary between large positive values and almost zero values. This variation causes instability in any list of absolute and relative threat levels. Once the list of threats has been stabilized, TS ranks them through the use of a prioritization function whose results are passed to RM.

An important issue remains to be addressed. Should stabilization of the outputs of TE (threat values) take place within the Threat Refinement module or at their origin (origin of the inputs of TE)? Future work on the Generic Model for STA should resolve this issue.

3.2.9 The Meta-controller

The information processing in STA plays a key role in the decision making concerning use of the ship's weapon and sensor systems in the Above Water Warfare (AWW). However, in a manner analogous to human information processing itself, it needs to be controlled and regulated as part of a generally reflective executive function. This functional capability in the generic model is provided by the Meta-controller.

The requirement for a Meta-controller can be traced to a number of critical characteristics of the AWW environment which is highly dynamic. Critical events happen at indeterminate times, and at any given moment multiple contacts may be under investigation, assessment and evaluation, at various stages in their processing chain. There can be time-varying priorities on processing a particular contact, depending on the perceived risk to the achievement of mission goals posed by the contact. The processing itself needs to account for the time pressure for producing its results, for example, by limiting the amount of information used in doing the processing. The information available in the AWW may be ambiguous, incomplete, erroneous, or imprecise. Information quality therefore needs to be monitored for its effect on the amount and nature of the processing required. Initiating actions (involving sensor management, navigation maneuvers, etc.) to acquire additional information in support of further STA processing of a contact may also be part of the Meta-controller's executive strategy in cases of inadequate information on that contact.

The Meta-controller therefore provides the necessary flexibility for monitoring the status of STA processing and opportunistically controlling this processing so as to respond to the various data-driven and goal-driven demands on this processing as events in AWW unfold.

3.3 Limitations of the Model

The generic model only illustrated a philosophy for building a system that assesses a tactical situation and its related threats. It is based on an attempt to understand the human's cognitive processes that derive his/her mental representation (or situation awareness) of the state of the world.

The methodology for building this model is not addressed in this document. A requirements definition is needed to address issues, such as decision-making requirements, task/function identification and automation at a generic level, through a top-down analysis of the problem. Toward the validation, refinement and development of the generic model, knowledge of the human's cognitive processing is essential and is at the heart of this approach. Expertise in the domain of cognitive science will be needed to look at issues such as tradeoffs in resources, task/function frameworks consistent with the multi-level cognitive representation of Situation Awareness, the control framework for invoking these functions (goal driven vs data driven), and mechanisms for the meta-control of STA operations. These research activities are essential to validate the generic model and lead to its eventual implementation.

Other research topics such as information warfare and a model for handling imperfect information in the STA process are important issues not addressed by this generic model which need to be investigated to enhance or refine the generic model.

3.4 Future Work

A subset of all the functionalities within the generic model, called a baseline for STA, is currently being implemented through a collaborative activity between Lockheed Martin Canada and the Defence Research Establishment of Valcartier (DREV). The complete implementation of the baseline is scheduled for 1998.

Short-term work will refine our understanding of the human's cognitive processes for achieving a situational awareness by conducting a top-down analysis of the problem in order to define the human's decision requirements according to a established cognitive engineering methodology.

Medium-term work will consist mainly of investigations and study to acquire expertise in the area of cognitive science, situation awareness, information warfare and uncertainty management. The expertise gained is expected to yield an enhanced generic model for STA.

The short-term and medium-term work will be accomplished through local R&D investigations and through collaborations with international partners, universities and industries.

4.0 CONCLUSION

This document presented a generic model for Situation and Threat Assessment. The proposed model is currently being used in an exploration of real-time issues for an integrated MSDF/STA/RM system for the CPF.

Unlike the traditional model of STA based on the level of abstraction of the data, the philosophy of the proposed model is concerned with the reinsertion of the human-in-the-loop by taking into consideration the human's mental processes that lead to the development of his/her situation awareness.

The generic model for STA evolved from the three-level Situation Awareness model of Endsley, knowledge and models of the human's cognitive processes, leading to a high-level functional decomposition of a multi-level STA process. This feature of the model leads to efficient automation of deliberative tasks within STA currently performed by human. In addition, this model allows the human to contribute actively to the STA process through the Human Computer Interface (HCI). Therefore, the implementation of the proposed model yields to a semi-automated advisory decision aids system.

A baseline of the generic model for STA is currently being implemented and integrated with baselines of MSDF and RM. The results of the implementation will be presented in a future document.

The results of this research are expected to contribute to DREV's investigations of enhancements to the CPF's CCIS as part of the mid-life upgrade of the CPF under the Frigate Life Extension Program (FELEX).

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